Street Sweeping

- *Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout Programs in the Chesapeake Bay Basin* – N. L. Law, et al, Center for Watershed Protection: http://www.worldsweeper.com/Street/Studies/CWPStudy/CBStreetSweeping.pdf
  - Pollutant Removal Efficiencies (%) from Street Sweeping for TP Watershed Load:

Frequency	Technology	TP
Monthly	Mechanical	3
	Air/Vacuum	4
Weekly	Mechanical	5
	Air/Vacuum	8

- *Preliminary Data Summary of Urban Storm Water Best Management Practices* – E. Strassler, J. Pritts and K. Strellec, EPA: http://www.epa.gov/waterscience/guide/stormwater/files/usw_d.pdf
  - Estimated Costs for Two Types of Street Sweepers:

Sweeper Type	Life (Years)	Purchase Price ($)	O&M Cost ($/curb mile)
Mechanical	5	75,000	30
Vacuum-assisted	8	150,000	15

  - Annualized US Street Sweeping Cost Information:

Annualized Sweeper Costs		
Sweeping Frequency	Mechanical Sweeper	Vacuum-Assisted Sweeper
Weekly	$1680/curb mi/yr	$946/curb mi/yr
Bi-weekly	$840/curb mi/yr	$473/curb mi/yr
Monthly	$388/curb mi/yr	$218/curb mi/yr
Quarterly	$129/curb mi/yr	$73/curb mi/yr
Semi-annually	$65/curb mi/yr	$36/curb mi/yr
Annually	$32/curb mi/yr	$18/curb mi/yr

- *Street Sweeping Cost per Curb Mile Worksheet*: http://www.worldsweeper.com/Street/Forms/curbmile.html
- *Street Sweeping* – Howard County Maryland Government: http://www.co.ho.md.us/DPW/street_sweep.htm
  - "Large quantities of leaves will clog sweeper filters, spreading the leaves over a large area"
  - Also have yard waste collection
- *Street Sweeping Helps in Maintaining Good Air Quality* – GreenDOC: http://www.greendoc.net/view/189039/street_sweeping_helps_in_maintaining_good_air_quality
- *Road and Street Maintenance* – California Stormwater BMP Handbook: http://www.cabmphandbooks.com/Documents/Municipal/SC-70.pdf
  - Mechanical brooms create more airborne dust particles. Vacuum sweepers noisier, may require an advance vehicle to remove large debris, and are ineffective at cleaning wet streets

- *Municipal Sweepers* – S. G. Bennett Marketing Services (Canada): http://www.sgbennett.com/municipal/sweepers.PDF
    - Compares prices of different street sweeping brands/models

Leaf Litter

- *Leaves as Source of Phosphorus* – W. F. Cowen and G. F. Lee: http://www.gfredlee.com/Nutrients/CowenLeavesP.pdf
    - 54-230µg soluble reactive phosphorus (SRP) leached per gram of in tact, oven-dried oak leaves (oak leaves leach less than poplar leaves, the only other type studied)
        - Mass leached directly related to length of soaking period
    - 650µg SRP per gram of cut-up, oven-dried oak leaves
    - 350µg SRP per gram of elm seeds
- *Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin, 1994-95* – R. J. Waschbusch, W. R. Selbig and R. T. Bannerman: http://wi.water.usgs.gov/pubs/WRIR-99-4021/WRIR-99-4021.pdf
    - Phosphorus from leaves contributed 30% to total phosphorus from street dirt samples (Street Load) collected using industrial vacuum equipment; at least 25% for each particle size (>250µm, 250-63µm, 63-25µm, <25µm)
- Cost Comparisons for Leaf Collection Programs
    - Alliance, OH (9 pieces of equipment used for 1,781 hours; 2,950 hours of labor): http://www.cityofalliance.com/admin/columns/Leaf%20Collection.htm
    - Haverford, PA (estimate includes cost of 2 mo. of labor, equipment and fuel): http://www.delcotimes.com/articles/2009/04/10/news/doc49debba6612b7746623324.txt
    - Waltham, MA (includes labor, maintenance of equipment, mechanical work, fuel costs and parts, and payment for a supervisor and two employees to run the program on Saturdays): http://www.dailynewstribune.com/homepage/x726977778/Cost-forces-city-to-scrap-its-leaf-vacuuming-program

Town	Population (2000 Census)	Total Land Area	Cost of Program
Alliance, OH	23,253	8.6 sq. mi.	$88,869.63
Haverford, PA	49,608	?	$582,522
Waltham, MA	59,266	12.7 sq. mi.	$270,000
Milford	26,799	14.6 sq. mi.	
Bellingham	15,314	18.5 sq. mi.	
Franklin	29,560	26.7 sq. mi.	

- *Expanded Leaf Collection Program* – Public Works Department, Rock Island, IL: http://www2.rigov.org/clerk/Agenda/120808/Public%20Works/expanded%20leaf%20collection%20program%20120208.pdf
    - Cost comparison of leaf collection via bags vs. via vacuums:
        - Leaf vacuuming: increase solid waste budget by $280,000 per year, divert 4,480 additional labor hours from infrastructure maintenance to fall leaf collection

    - Leaf bag pickup: increase solid waste budget by $98,000 per year, divert 640 additional labor hours from infrastructure maintenance each season
- *Leaf Collection & Giveaway* – Town of Blacksburg, VA: http://www.blacksburg.va.us/Index.aspx?page=843
    - Town will not collect leaves on private roads, private property, or in parking lots

Catch Basins

- *Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout Programs in the Chesapeake Bay Basin* – N. L. Law, et al, Center for Watershed Protection: http://www.worldsweeper.com/Street/Studies/CWPStudy/CBStreetSweeping.pdf
    - Pollutant Removal Rates (%) from Catch Basin Cleanouts for TP Watershed Load:

Frequency	TP
Annual	<1
Semi-Annual	2

- *Pollution Prevention Fact Sheets: Catch Basins* – Stormwater Manager's Resource Center: http://www.stormwatercenter.net/Pollution_Prevention_Factsheets/CatchBasins.htm
    - Pre-cast Catch Basin: $2,000-$3,000
    - Vactor Truck: $125,000-$150,000
    - 1 truck can clean 750-1000 catch basins
- *Storm Water O&M Fact Sheet – Catch Basin Cleaning* – EPA: http://www.p2pays.org/ref/17/16087.pdf
    - $8 / basin with vacuum street sweepers
    - $16 / basin manually

Phosphorus-free Fertilizer

- *Phosphorus Fertilizer Ordinance* – City of Ann Arbor: http://www.a2gov.org/GOVERNMENT/PUBLICSERVICES/SYSTEMS_PLANNING/ENVIRONMENT/Pages/PhosphorusFertilizer.aspx
    - Malletts Creek Restoration Study: 100% compliance would reduce phosphorus loading by 560 lbs/yr (0.08 lbs/acre/yr)
    - Phosphorus load from Malletts Creek to Huron River from May-Oct modeled at 2500 lbs
    - Extrapolating this to Ann Arbor creeksheds would result in a 22% reduction in phosphorus loading to the Huron River
- *Assessment of Source Reduction due to Phosphorus-free Fertilizers* –B.J. Vlach, J. Barten, J. Johnson, and M. Zachay: http://wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_115795.pdf
    - Plymouth – Phosphorus-free fertilizer
      Maple Grove – Phosphorus-containing fertilizer
    - P-free fertilizer can reduce P export from residential areas by 12-16%
    - SRP concentration in runoff 17% lower at P-free sites; TP concentrations about equal at each site

- *Evidence for Reduced River Phosphorus Following Implementation of a Lawn Fertilizer Ordinance* – J. T. Lehman, D. W. Bell and K. E. McDonald: http://www.a2gov.org/government/publicservices/systems_planning/Environment/Documents/FertilizerStudyYear1.pdf
  - Huron River, MI: no significant difference in SRP concentrations when comparing 2003-2005 values with 2008 values
  - Statistically significant DP reductions in 2 out of 10 cases (2 sites examined for 5 months each), with a mean reduction of 18%. Reduced monthly mean concentrations at site B in each of the 5 months (just not statistically significant)
  - Statistically significant TP reductions in 6 out of 10 cases, with a mean reduction of 31%
- *Green Lawns – Green Lakes: The Phosphorus Connection* – J. Barten: http://www.danewaters.com/pdf/20031010_greenlawn.pdf
  - Approximately 25 pounds of phosphorus is added to lakes, wetlands and streams each year from a 100 acre residential development

Pet Waste

- *Calculating the Pollution Savings* – Make Maryland Great
  - Cat and dog feces contain about 0.25% phosphate (by mass?)
  - Give 1% credit for feces disposal
- *Stormwater Pollution: Getting at the Source* – Stormwater Journal Nov-Dec 2007: http://www.reefrelief.org/scientificstudies/stormwater_pollution.pdf
  - a 20-kg dog excretes about 4.2 kg of N and 0.9 kg of P per year

Aquatic Plant Harvesting

- *Phosphorus and Aquatic Plants* – G. Thiébaut: http://www.springerlink.com/content/t89142176676914m/fulltext.pdf
  - P: 0.1-1.2% of dry weight (concentration range among various species)
- *Seagrass Nutrient Content* – C. M. Duarte: http://www.int-res.com/articles/meps/67/m067p201.pdf
  - P: 0.2% of dry weight (median concentration among various species)
- AquaFiber Technologies Corporation: http://www.aquafiber.com/index.html
  - 2003: could remove 35 lbs P/acre/yr using periphyton floways
    2005: 200 lbs P/acre/yr using periphyton floways and ozone
    2008: 53,000 lbs P/acre/yr using AquaLutions
  - Contract with St. John's River Water Management District to remove 1 metric ton P/yr from Lake Jesup in Florida; also has research and development facility on Lake Apopka in Florida
- *Agenda Request for Governing Board Meeting April 10, 2007* – St. John's River Water Management District: http://www.sjrwmd.com/governingboard/pdfs/2007/gb0704/gb0704_018.pdf
  - Contract with AquaFiber: $500,000/yr for 5 years to remove 1 MT P/yr ($227/lb)
- *Consumptive Use Technical Staff Report* – St. John's River Water Management District: http://www.sjrwmd.com/governingboard/pdfs/2008/rg0808/rg0808_004.pdf
  - 5-year permit to remove 7.5 MGD from Lake Jesup and return all but 0.02 MGD after treatment

- *Harvesting and Phosphorus Control in Long Lake – Technical Memorandum, Thurston County, Washington* – EnviroVision Corp: http://www.co.thurston.wa.us/stormwater/Lakes/Long%20Lake/Long%20Lake%20Integrated%20Plan/LongLkTechMemoFinal.pdf
  - Assumed P concentration of 0.21% of dry weight
  - Harvesting 45 acres to a depth of 5m, assuming 75% of biomass is removed, would result in a P load reduction of 47.6 kg (4-7% of annual load to Long Lake)
  - Actual effect of harvesting:

	Shallow Water		Deep Water	
	1-3 hours later	24 hours later	1-3 hours later	24 hours later
[SRP]	No Change	Decrease	No Change	Increase
[TP]	No Change	Increase	No Change	Increase

    Decrease in SRP and increase in TP 24 hours after harvest in shallow waters possibly do to algal bloom
  - Harvesting can result in the release of P from:
    - Decomposition of plant fragments not collected by harvesters
    - Leaching of phosphorus from cut plant stems
    - Re-suspension of lake sediments during harvesting
- *Control of Phosphorus by Harvesting and Alum* – E. B. Welch, University of Washington Department of Civil and Environmental Engineering: http://www.ce.washington.edu/pub/WRS/WRS152
  - Used the Aquatics Unlimited H5-200 for macrophyte harvesting
  - Assumed P concentration of 0.3% of dry weight
  - Removed up to 69% of whole-lake biomass, but whole-lake biomass changed little; harvesting could not keep up with regrowth. However, new plants were bushier and shorter, creating more open water.
  - Harvesting had little effect on whole-lake TP
    - TP concentration highest in 1990, when most biomass removed (lake quality also poorest, as judged by chlorophyll a concentration and transparency, but probably not *due to* harvesting)
    - TP concentration declined in 1991, the first year without harvesting
    - Predicted reason: "absence of the plants from large areas probably exposed sediments to wind-caused resuspension of particulate P or else a high-P anaerobic boundary layer near the sediment-water interface"
    - Plant harvesting coincided with decreased organic content of surficial sediments and SOD, but harvesting may not have been the cause
- *Macrophyte Control by Harvesting and Herbicides: Implications for Phosphorus Cycling in Lake Wingra, Wisconsin* – S.R. Carpenter and M.S. Adams: http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=ENV&recid=7900771&q=Carpenter+phosphorus+harvesting&uid=788135013&setcookie=yes
  - "Harvesting Eurasian water milfoil (Myriophyllum spicatum) from shallow, eutrophic Lake Wingra, in Madison, Wisconsin, would remove an equivalent 37% annual net phosphorus load"

- *Advantages and Disadvantages of Aquatic Plant Management Techniques* – J. D. Madsen, PhD: http://www.aquatics.org/pubs/madsen2.htm
  - Hand cutting/pulling very effective in very localized areas; harvesting resuspends sediments and is non-selective
  - "Harvesting removes large numbers of macroinvertebrates, semi-aquatic vertebrates, forage fishes, young-of-the-year fishes, and even adult gamefishes"
  - "Removal of large amounts of plants can improve the diel oxygen balance of littoral zones and rivers, particularly in shallower water"
  - Reduction of TP inputs in 3 lakes:
    - Lake Wingra, WI: TP input decreased by 37% (or theoretically would? see previous Carpenter & Adams study above)
    - Chemung Lake, Ontario: TP input decreased by 20% (discrepancy with number below – see Wile study)
    - Sallie Lake, MN (more eutrophic): harvesting in the littoral zone decreased TP input by 1.4% (http://www.jstor.org/pss/25038183)
    - However, in none of these was the internal P pool reduced
- *Aquatic Plant Management – Mechanical Harvesting* – WA Department of Ecology: http://www.ecy.wa.gov/Programs/wq/plants/management/aqua026.html
  - Costs as low as $250/acre. Private contractors generally charge $500-800/acre."
  - Cost of harvester between $35,000 and $110,000
- *Cost and Productivity in Harvesting of Aquatic Plants* – R. G. Koegel, D. F. Livermore, & H.D. Bruhn: http://www.apms.org/japm/vol15/v15p12.pdf
  - 1973 seasonal average harvesting rate and cost for two mechanical harvesters: 0.73 acres/hr for $60.00/hr
- *Aquatic Plants in Dane County Waters* – Dane County Lakes and Watershed Commission: http://www.danewaters.com/pdf/20030811_aquatic_lake_mgmt.pdf
  - 2003 Dane County aquatic plant harvesting budget: $107,700 from solid waste fund (7 harvesters, employees hired from mid-May to mid-August)
  - Harvesters trained to try to avoid native species that do not form nuisance growth and focus on cutting invasive species
  - Dane County must submit lake aquatic plant harvesting plans for approval from the Wisconsin Department of Natural Resources (for which Roger Bannerman works!)
- *Environmental Effects of Mechanical Harvesting* – I. Wile: http://www.apms.org/japm/vol16/v16p14.pdf
  - 1975: Removed $3x10^6$ kg of aquatic plants (wet weight?) containing 560 kg P (~0.02%). Equivalent of a 47% reduction in gross annual P load and a 92% reduction in net annual P load.
  - Plant tissue concentration of P: 0.13-0.60% of dry weight
  - Harvesting only in southern part of Chemung Lake, Ontario. TP concentration (µg/l) in southern and northern sections of the lake:

	1971	1972	1973	1974	1975	1976
C2 (North)	23	23	18	27	19	19
C3 (North)	26	21	16	20		
C1 (South)	27	24	24	31	23	23
C4 (South)	32	30	26	33	23	23

So TP concentrations were actually higher where there was harvesting.

- 1.4% P load reduction in Lake Sallie, MN from harvesting – reasons for drastic difference between Lake Sallie and Chemung Lake P reductions:
    - Only 4.28×10^5 kg plants harvested from Lake Sallie vs. 3×10^6 kg from southern Chemung Lake
    - Macrophytes cover only 158 ha of Lake Sallie, but 435 ha of southern Chemung Lake
    - Annual P load to Lake Sallie is 7285 kg vs. 1190 kg to southern Chemung Lake